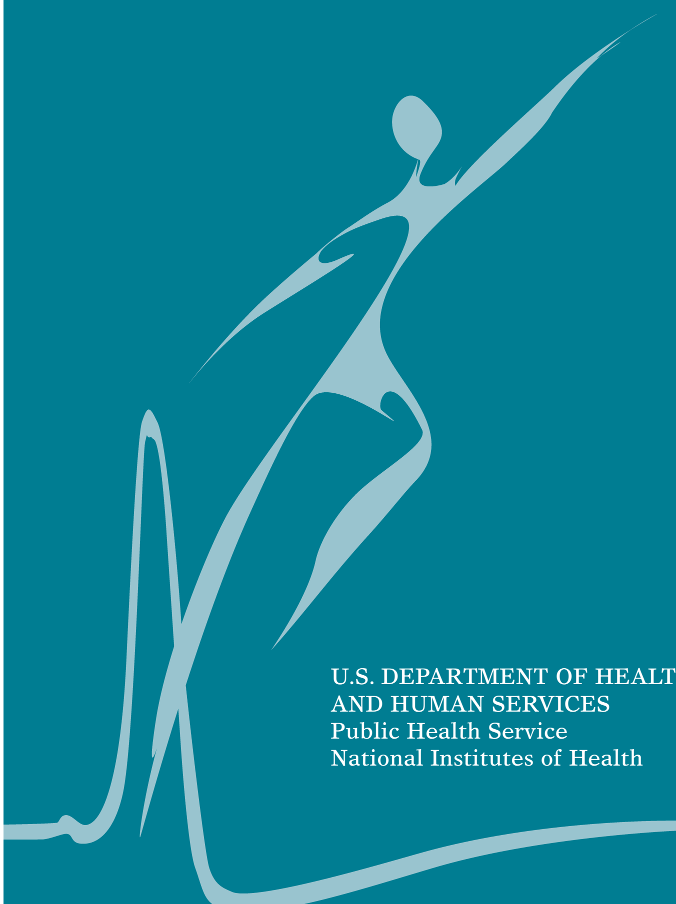
Neurological Diagnostic Tests and Procedures



U.S. DEPARTMENT OF HEALTH
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Neurological Diagnostic Tests and Procedures

Diagnostic tests and procedures are vital tools that help physicians confirm or rule out the presence of a neurological disorder or other medical condition. A century ago, the only way to make a positive diagnosis for many neurological disorders was by performing an autopsy after a patient had died. But decades of basic research into the characteristics of disease, and the development of techniques that allow scientists to see inside the living brain and monitor nervous system activity as it occurs, have given doctors powerful and accurate tools to diagnose disease and to test how well a particular therapy may be working.

Perhaps the most significant changes in diagnostic imaging over the past 20 years are improvements in spatial resolution (size, intensity, and clarity) of anatomical images and reductions in the time needed to send signals to and receive data from the area being imaged. These advances allow physicians to simultaneously see the structure of the brain and the changes in brain activity as they occur. Scientists continue to improve methods that will provide sharper anatomical images and more detailed functional information.

Researchers and physicians use a variety of diagnostic imaging techniques and chemical and metabolic analyses to detect, manage, and treat neurological disease. Some procedures are performed in specialized settings, conducted to determine the presence of a particular disorder or abnormality. Many tests that were previously conducted in a hospital are now performed in a physician's office or at an outpatient testing facility, with little if any risk to the patient. Depending on the type of procedure, results are either immediate or may take several hours to process.

What are some of the more common screening tests?

Laboratory screening tests of blood, urine, or other substances are used to help diagnose disease, better understand the disease process, and monitor levels of therapeutic drugs. Certain tests, ordered by the physician as part of a regular check-up, provide general information, while others are used to identify specific health concerns. For example, blood and blood product tests can detect brain and/or spinal cord infection, bone marrow disease, hemorrhage, blood vessel damage, toxins that affect the nervous system, and the presence of antibodies that signal the presence of an autoimmune disease. Blood tests are also used to monitor levels of therapeutic drugs used to treat epilepsy and other neurological disorders. Genetic testing of DNA extracted from white cells in the blood can help diagnose Huntington's disease and other congenital diseases. Analysis of the fluid that surrounds the brain and spinal cord can detect meningitis, acute and chronic inflammation, rare infections, and some cases of multiple sclerosis. Chemical and metabolic testing of the blood can indicate protein disorders, some forms of muscular dystrophy and other muscle disorders, and diabetes. Urinalysis can reveal abnormal substances in the urine or the presence or absence of certain proteins that cause diseases including the mucopolysaccharidoses.

Genetic testing or counseling can help parents who have a family history of a neurological disease determine if they are carrying one of the known genes that cause the disorder or find out if their child is affected. Genetic testing can identify many neurological disorders, including spina bifida, in utero (while the child is inside the mother's womb). Genetic tests include the following:

- *Amniocentesis*, usually done at 14–16 weeks of pregnancy, tests a sample of the amniotic fluid in the womb for genetic defects (the fluid and the fetus have the same DNA). Under local anesthesia, a thin needle is inserted through the woman's abdomen and into the womb. About 20 milliliters of fluid (roughly 4 teaspoons) is withdrawn and sent to a lab for evaluation. Test results often take 1–2 weeks.

- *Chorionic villus sampling*, or CVS, is performed by removing and testing a very small sample of the placenta during early pregnancy. The sample, which contains the same DNA as the fetus, is removed by catheter or fine needle inserted through the cervix or by a fine needle inserted through the abdomen. It is tested for genetic abnormalities and results are usually available within 2 weeks. CVS should not be performed after the tenth week of pregnancy.

- *Uterine ultrasound* is performed using a surface probe with gel. This noninvasive test can suggest the diagnosis of conditions such as chromosomal disorders (see ultrasound imaging, below).

What is a neurological examination?

A ***neurological examination*** assesses motor and sensory skills, the functioning of one or more cranial nerves, hearing and speech, vision, coordination and balance, mental status, and changes in mood or behavior, among other abilities. Items including a tuning fork, flashlight, reflex hammer, ophthalmoscope, and needles are used to help diagnose brain tumors, infections such as encephalitis and meningitis, and diseases such as Parkinson's disease, Huntington's disease, amyotrophic lateral sclerosis (ALS), and epilepsy. Some tests require the services of a specialist to perform and analyze results.

X-rays of the patient's chest and skull are often taken as part of a neurological work-up. X-rays can be used to view any part of the body, such as a joint or major organ system. In a conventional x-ray, also called a radiograph, a technician passes a concentrated burst of low-dose ionized radiation through the body and onto a photographic plate. Since calcium in bones absorbs x-rays more easily than soft tissue or muscle, the bony structure appears white on the film. Any vertebral misalignment or fractures can be seen within minutes. Tissue masses such as injured ligaments or a bulging disc are not visible on conventional x-rays. This fast, noninvasive, painless procedure is usually performed in a doctor's office or at a clinic.

Fluoroscopy is a type of x-ray that uses a continuous or pulsed beam of low-dose radiation to produce continuous images of a body part in motion. The fluoroscope (x-ray tube) is focused on the area of interest and pictures are either videotaped or sent to a monitor for viewing. A contrast medium may be used to highlight the images. Fluoroscopy can be used to evaluate the flow of blood through arteries.

What are some tests used to diagnose neurological disorders?

Based on the result of a neurological exam, physical exam, patient history, x-rays of the patient's chest and skull, and any previous screening or testing, physicians may order one or more of the following diagnostic tests to determine the specific nature of a suspected neurological disorder or injury. These diagnostics generally involve either *nuclear medicine imaging*, in which very small amounts of radioactive materials are used to study organ function and structure, or *diagnostic imaging*, which uses magnets and electrical charges to study human anatomy.

The following list of available procedures—in alphabetical rather than sequential order—includes some of the more common tests used to help diagnose a neurological condition.

Angiography is a test used to detect blockages of the arteries or veins. A *cerebral angiogram* can detect the degree of narrowing or obstruction of an artery or blood vessel in the brain, head, or neck. It is used to diagnose stroke and to determine the location and size of a brain tumor, aneurysm, or vascular malformation. This test is usually performed in a hospital outpatient setting and takes up to 3 hours, followed by a 6- to 8-hour resting period. The patient, wearing a hospital or imaging gown, lies on a table that is wheeled into the imaging area. While the patient is awake, a physician anesthetizes a small area of the leg near the groin and then inserts a catheter into a major artery located there. The catheter is threaded through the body and into an artery in the neck. Once the catheter is in place, the needle is removed and a guide wire is inserted. A small capsule containing a radiopaque dye (one that is highlighted on x-rays) is passed over the guide wire to the site of release. The dye is released and travels through the bloodstream into the head and neck. A series of x-rays is taken and any obstruction is noted. Patients may feel a warm to hot sensation or slight discomfort as the dye is released.

Biopsy involves the removal and examination of a small piece of tissue from the body. *Muscle* or *nerve biopsies* are used to diagnose neuromuscular disorders and may also reveal if a person is a carrier of a defective gene that could be passed on to children. A small sample of muscle or nerve is removed under local anesthetic and studied under a microscope. The sample may be removed either surgically, through a slit made in the skin, or by needle biopsy, in which a thin hollow needle is inserted through the skin and into the muscle. A small piece of muscle or nerve remains in the hollow needle when it is removed from the body. The biopsy is usually performed at an outpatient testing facility. A *brain biopsy*, used to determine tumor type, requires surgery to remove a small piece of the brain or tumor. Performed in a hospital, this operation is riskier than a muscle biopsy and involves a longer recovery period.

Brain scans are imaging techniques used to diagnose tumors, blood vessel malformations, or hemorrhage in the brain. These scans are used to study organ function or injury or disease to tissue or muscle. Types of brain scans include computed tomography, magnetic resonance imaging, and positron emission tomography (see descriptions, below).

Cerebrospinal fluid analysis involves the removal of a small amount of the fluid that protects the brain and spinal cord. The fluid is tested to detect any bleeding or brain hemorrhage, diagnose infection to the brain and/or spinal cord, identify some cases of multiple sclerosis and other neurological conditions, and measure intracranial pressure.

The procedure is usually done in a hospital. The sample of fluid is commonly removed by a procedure known as a *lumbar puncture*, or *spinal tap*. The patient is asked to either lie on one side, in a ball position with knees close to the chest, or lean forward while sitting on a table or bed. The doctor will locate a puncture site in the lower back, between two vertebrate, then clean the area and inject a local anesthetic. The patient may feel a slight stinging sensation from this injection. Once the anesthetic has taken effect, the doctor will insert a special needle into the spinal sac and remove a small amount of fluid (usually about 3 teaspoons) for testing. Most patients will feel a sensation of pressure only as the needle is inserted.

A common after-effect of a lumbar puncture is headache, which can be lessened by having the patient lie flat. Risk of nerve root injury or infection from the puncture can occur but it is rare. The entire procedure takes about 45 minutes.

Computed tomography, also known as a CT scan, is a noninvasive, painless process used to produce rapid, clear two-dimensional images of organs, bones, and tissues. Neurological CT scans are used to view the brain and spine. They can detect bone and vascular irregularities, certain brain tumors and cysts, herniated discs, epilepsy, encephalitis, spinal stenosis (narrowing of the spinal canal), a blood clot or intracranial bleeding in patients with stroke, brain damage from head injury, and other disorders. Many neurological disorders share certain characteristics and a CT scan can aid in proper diagnosis by differentiating the area of the brain affected by the disorder.

Scanning takes about 20 minutes (a CT of the brain or head may take slightly longer) and is usually done at an imaging center or hospital on an outpatient basis. The patient lies on a special table that slides into a narrow chamber. A sound system built into the chamber allows the patient to communicate with the physician or technician. As the patient lies still, x-rays are passed through the body at various angles and are detected by a computerized scanner. The data is processed and displayed as cross-sectional images, or "slices," of the internal structure of the body or organ. A light sedative may be given to patients who are unable to lie still and pillows may be used to support and stabilize the head and body. Persons who are claustrophobic may have difficulty taking this imaging test.

Occasionally a contrast dye is injected into the bloodstream to highlight the different tissues in the brain. Patients may feel a warm or cool sensation as the dye circulates through the bloodstream or they may experience a slight metallic taste.

Although very little radiation is used in CT, pregnant women should avoid the test because of potential harm to the fetus from ionizing radiation.

Discography is often suggested for patients who are considering lumbar surgery or whose lower back pain has not responded to conventional treatments. This outpatient procedure is usually performed at a testing facility or a hospital. The patient is asked to put on a metal-free hospital gown and lie on an imaging table. The physician numbs the skin with anesthetic and inserts a thin needle, using x-ray guidance, into the spinal disc. Once the needle is in place, a small amount of contrast dye is injected and CT scans are taken. The contrast dye outlines any damaged areas. More than one disc may be imaged at the same time. Patient recovery usually takes about an hour. Pain medicine may be prescribed for any resulting discomfort.

An ***intrathecal contrast-enhanced CT scan*** (also called cisternography) is used to detect problems with the spine and spinal nerve roots. This test is most often performed at an imaging center. The patient is asked to put on a hospital or imaging gown. Following application of a topical anesthetic, the physician removes a small sample of the spinal fluid via lumbar puncture. The sample is mixed with a contrast dye and injected into the spinal sac located at the base of the lower back. The patient is then asked to move to a position that will allow the contrast fluid to travel to the area to be studied. The dye allows the spinal canal and nerve roots to be seen more clearly on a CT scan. The scan may take up to an hour to complete. Following the test, patients may experience some discomfort and/or headache that may be caused by the removal of spinal fluid.

Electroencephalography, or EEG, monitors brain activity through the skull. EEG is used to help diagnose certain seizure disorders, brain tumors, brain damage from head injuries, inflammation of the brain and/or spinal cord, alcoholism, certain psychiatric disorders, and metabolic and degenerative disorders that affect the brain. EEGs are also used to evaluate sleep disorders, monitor brain activity when a patient has been fully anesthetized or loses consciousness, and confirm brain death.

This painless, risk-free test can be performed in a doctor's office or at a hospital or testing facility. Prior to taking an EEG, the person must avoid caffeine intake and prescription drugs that affect the nervous system. A series of cup-like electrodes are attached to the patient's scalp, either with a special conducting paste or with extremely fine needles. The electrodes (also called leads) are small devices that are attached to wires and carry the electrical energy of the brain to a machine for reading. A very low electrical current is sent through the electrodes and the baseline brain energy is recorded. Patients are then exposed to a variety of external stimuli—including bright or flashing light, noise, or certain drugs—or are asked to open and close the eyes, or to change breathing patterns. The electrodes transmit the resulting changes in brain wave patterns. Since movement and nervousness can change brain wave patterns, patients usually recline in a chair or on a bed during the test, which takes up to an hour. Testing for certain disorders requires performing an EEG during sleep, which takes at least 3 hours.

In order to learn more about brain wave activity, electrodes may be inserted through a surgical opening in the skull and into the brain to reduce signal interference from the skull.

Electromyography, or EMG, is used to diagnose nerve and muscle dysfunction and spinal cord disease. It records the electrical activity from the brain and/or spinal cord to a peripheral nerve root (found in the arms and legs) that controls muscles during contraction and at rest.

During an EMG, very fine wire electrodes are inserted into a muscle to assess changes in electrical voltage that occur during movement and when the muscle is at rest. The electrodes are attached through a series of wires to a recording instrument. Testing usually takes place at a testing facility and lasts about an hour but may take longer, depending on the number of muscles and nerves to be tested. Most patients find this test to be somewhat uncomfortable.

An EMG is usually done in conjunction with a ***nerve conduction velocity (NCV)*** test, which measures electrical energy by assessing the nerve's ability to send a signal. This two-part test is conducted most often in a hospital. A technician tapes two sets of flat electrodes on the skin over the muscles. The first set of electrodes is used to send small pulses of electricity (similar to the sensation of static electricity) to stimulate the nerve that directs a particular muscle. The second set of electrodes transmits the responding electrical signal to a recording machine. The physician then reviews the response to verify any nerve damage or muscle disease. Patients who are preparing to take an EMG or NCV test may be asked to avoid caffeine and not smoke for 2 to 3 hours prior to the test, as well as to avoid aspirin and non-steroidal anti-inflammatory drugs for 24 hours before the EMG. There is no discomfort or risk associated with this test.

Electronystagmography (ENG) describes a group of tests used to diagnose involuntary eye movement, dizziness, and balance disorders, and to evaluate some brain functions. The test is performed at an imaging center. Small electrodes are taped around the eyes to record eye movements. If infrared photography is used in place of electrodes, the patient wears special goggles that help record the information. Both versions of the test are painless and risk-free.

Evoked potentials (also called evoked response) measure the electrical signals to the brain generated by hearing, touch, or sight. These tests are used to assess sensory nerve problems and confirm neurological conditions including multiple sclerosis, brain tumor, acoustic neuroma (small tumors of the inner ear), and spinal cord injury. Evoked potentials are also used to test sight and hearing (especially in infants and young children), monitor brain activity among coma patients, and confirm brain death.

Testing may take place in a doctor's office or hospital setting. It is painless and risk-free. Two sets of needle electrodes are used to test for nerve damage. One set of electrodes, which will be used to measure the electrophysiological response to stimuli, is attached to the patient's scalp using conducting paste. The second set of electrodes is attached to the part of the body to be tested. The physician then records the amount of time it takes for the impulse generated by stimuli to reach the brain. Under normal circumstances, the process of signal transmission is instantaneous.

Auditory evoked potentials (also called brain stem auditory evoked response) are used to assess high-frequency hearing loss, diagnose any damage to the acoustic nerve and auditory pathways in the brainstem, and detect acoustic neuromas. The patient sits in a soundproof room and wears headphones. Clicking sounds are delivered one at a time to one ear while a masking sound is sent to the other ear. Each ear is usually tested twice, and the entire procedure takes about 45 minutes.

Visual evoked potentials detect loss of vision from optic nerve damage (in particular, damage caused by multiple sclerosis). The patient sits close to a screen and is asked to focus on the center of a shifting checkerboard pattern. Only one eye is tested at a time; the other eye is either kept closed or covered with a patch. Each eye is usually tested twice. Testing takes 30–45 minutes.

Somatosensory evoked potentials measure response from stimuli to the peripheral nerves and can detect nerve or spinal cord damage or nerve degeneration from multiple sclerosis and other degenerating diseases. Tiny electrical shocks are delivered by electrode to a nerve in an arm or leg. Responses to the shocks, which may be delivered for more than a minute at a time, are recorded. This test usually lasts less than an hour.

Magnetic resonance imaging (MRI) uses computer-generated radio waves and a powerful magnetic field to produce detailed images of body structures including tissues, organs, bones, and nerves. Neurological uses include the diagnosis of brain and spinal cord tumors, eye disease, inflammation, infection, and vascular irregularities that may lead to stroke. MRI can also detect and monitor degenerative disorders such as multiple sclerosis and can document brain injury from trauma.

The equipment houses a hollow tube that is surrounded by a very large cylindrical magnet. The patient, who must remain still during the test, lies on a special table that is slid into the tube. The patient will be asked to remove jewelry, eyeglasses, removable dental work, or other items that might interfere with the magnetic imaging. The patient should wear a sweat shirt and sweat pants or other clothing free of metal eyelets or buckles. MRI scanning equipment creates a magnetic field around the body strong enough to temporarily realign water molecules in the tissues. Radio waves are then passed through the body to detect the "relaxation" of the molecules back to a random alignment and trigger a resonance signal at different angles within the body. A computer processes this resonance into either a three-dimensional picture or a two-dimensional "slice" of the tissue being scanned, and differentiates between bone, soft tissues, and fluid-filled spaces by their water content and structural properties. A contrast dye may be used to enhance visibility of certain areas or tissues. The patient may hear grating or knocking noises when the magnetic field is turned on and off. (Patients may wear special earphones to block out the sounds.) Unlike CT scanning, MRI does not use ionizing radiation to produce images. Depending on the part(s) of the body to be scanned, MRI can take up to an hour to complete. The test is painless and risk-free, although persons who are obese or claustrophobic may find it somewhat uncomfortable. (Some centers also use open MRI machines that do not completely surround the person being tested and are less confining. However, open MRI does not currently provide the same picture quality as standard MRI and some tests may not be available using this equipment.) Due to the incredibly strong magnetic field generated by an MRI, patients with implanted medical devices such as a pacemaker should avoid the test.

Functional MRI (fMRI) uses the blood's magnetic properties to produce real-time images of blood flow to particular areas of the brain. An fMRI can pinpoint areas of the brain that become active and note how long they stay active. It can also tell if brain activity within a region occurs simultaneously or sequentially. This imaging process is used to assess brain damage from head injury or degenerative disorders such as Alzheimer's disease and to identify and monitor other neurological disorders, including multiple sclerosis, stroke, and brain tumors.

Myelography involves the injection of a water- or oil-based contrast dye into the spinal canal to enhance x-ray imaging of the spine. *Myelograms* are used to diagnose spinal nerve injury, herniated discs, fractures, back or leg pain, and spinal tumors.

The procedure takes about 30 minutes and is usually performed in a hospital. Following an injection of anesthesia to a site between two vertebrae in the lower back, a small amount of the cerebrospinal fluid is removed by spinal tap (see *cerebrospinal fluid analysis*, above) and the contrast dye is injected into the spinal canal. After a series of x-rays is taken, most or all of the contrast dye is removed by aspiration. Patients may experience some pain during the spinal tap and when the dye is injected and removed. Patients may also experience headache following the spinal tap. The risk of fluid leakage or allergic reaction to the dye is slight.

Positron emission tomography (PET) scans provide two- and three-dimensional pictures of brain activity by measuring radioactive isotopes that are injected into the bloodstream. PET scans of the brain are used to detect or highlight tumors and diseased tissue, measure cellular and/or tissue metabolism, show blood flow, evaluate patients who have seizure disorders that do not respond to medical therapy and patients with certain memory disorders, and determine brain changes following injury or drug abuse, among other uses. PET may be ordered as a follow-up to a CT or MRI scan to give the physician a greater understanding of specific areas of the brain that may be involved with certain problems. Scans are conducted in a hospital or at a testing facility, on an outpatient basis. A low-level radioactive isotope, which binds to chemicals that flow to the brain, is injected into the bloodstream and can be traced as the brain performs different functions. The patient lies still while overhead sensors detect gamma rays in the body's tissues. A computer processes the information and displays it on a video monitor or on film. Using different compounds, more than one brain function can be traced simultaneously. PET is painless and relatively risk-free. Length of test time depends on the part of the body to be scanned. PET scans are performed by skilled technicians at highly sophisticated medical facilities.

A ***polysomnogram*** measures brain and body activity during sleep. It is performed over one or more nights at a sleep center. Electrodes are pasted or taped to the patient's scalp, eyelids, and/or chin. Throughout the night and during the various wake/sleep cycles, the electrodes record brain waves, eye movement, breathing, leg and skeletal muscle activity, blood pressure, and heart rate. The patient may be videotaped to note any movement during sleep. Results are then used to identify any characteristic patterns of sleep disorders, including restless legs syndrome, periodic limb movement disorder, insomnia, and breathing disorders such as obstructive sleep apnea. Polysomnograms are noninvasive, painless, and risk-free.

Single photon emission computed tomography (SPECT), a nuclear imaging test involving blood flow to tissue, is used to evaluate certain brain functions. The test may be ordered as a follow-up to an MRI to diagnose tumors, infections, degenerative spinal disease, and stress fratures.

As with a PET scan, a radioactive isotope, which binds to chemicals that flow to the brain, is injected intravenously into the body. Areas of increased blood flow will collect more of the isotope. As the patient lies on a table, a gamma camera rotates around the head and records where the radioisotope has traveled. That information is converted by computer into cross-sectional slices that are stacked to produce a detailed three-dimensional image of blood flow and activity within the brain. The test is performed at either an imaging center or a hospital.

Thermography uses infrared sensing devices to measure small temperature changes between the two sides of the body or within a specific organ. Also known as digital infrared thermal imaging, thermography may be used to detect vascular disease of the head and neck, soft tissue injury, various neuromusculoskeletal disorders, and the presence or absence of nerve root compression. It is performed at an imaging center, using infrared light recorders to take thousands of pictures of the body from a distance of 5 to 8 feet. The information is converted into electrical signals which results in a computer-generated two-dimensional picture of abnormally cold or hot areas indicated by color or shades of black and white. Thermography does not use radiation and is safe, risk-free, and noninvasive.

Ultrasound imaging, also called ultrasound scanning or sonography, uses high-frequency sound waves to obtain images inside the body. *Neurosonography* (ultrasound of the brain and spinal column) analyzes blood flow in the brain and can diagnose stroke, brain tumors, hydrocephalus (build-up of cerebrospinal fluid in the brain), and vascular problems. It can also identify or rule out inflammatory processes causing pain. It is more effective than an x-ray in displaying soft tissue masses and can show tears in ligaments, muscles, tendons, and other soft tissue masses in the back. *Transcranial Doppler ultrasound* is used to view arteries and blood vessels in the neck and determine blood flow and risk of stroke.

During ultrasound, the patient lies on an imaging table and removes clothing around the area of the body to be scanned. A jelly-like lubricant is applied and a transducer, which both sends and receives high-frequency sound waves, is passed over the body. The sound wave echoes are recorded and displayed as a computer-generated real-time visual image of the structure or tissue being examined. Ultrasound is painless, noninvasive, and risk-free. The test is performed on an outpatient basis and takes between 15 and 30 minutes to complete.

What lies ahead?

Scientists funded by the National Institute of Neurological Disorders and Stroke (NINDS) seek to develop additional and improved screening methods to more accurately and quickly confirm a specific diagnosis and allow scientists to investigate other factors that might contribute to disease. Technological advances in imaging will allow researchers to better see inside the body, at less risk to the patient. These diagnostics and procedures will continue to be important clinical research tools for confirming a neurological disorder, charting disease progression, and monitoring therapeutic effect.

More information about neurological diagnostics is available from the following organizations:

American Association of Neurological Surgeons
5550 Meadowbrook Drive
Rolling Meadows, IL 60008
(847) 378-0500
(888) 566-AANS (2267)
www.aans.org

American College of Radiology
1891 Preston White Drive
Reston, VA 20191–4397
(800) 227–5463
www.acr.org

Radiological Society of North America
820 Jorie Boulevard
Oak Brook, IL 60523-2251
(630) 571-2670
www.radiologyinfo.org

National Library of Medicine
National Institutes of Health
8600 Rockville Pike
Bethesda, MD 20894
(301) 496-6308
www.nlm.nih.gov

For information on specific neurological disorders or research programs funded by the NINDS, contact the Institute's Brain Resources and Information Network (BRAIN) at:

BRAIN
P.O. Box 5801
Bethesda, MD 20824
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